APPRAISAL OF WATER QUALITY NEEDS AND CRITERIA FOR EVERGLADES NATIONAL PARK

U.S. DEPARTMENT OF THE INTERIOR
NATIONAL PARK SERVICE
WASHINGTON, D.C.
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PURPOSE

This statement is designed to present historical information on the quality of water in Everglades National Park and on the water quality requirements of the park in response to Senate Report No. 91-895, 91st Congress, which requests "that the National Park Service prepare a report on the water quality needs of the park and the extent to which they are being met." The Senate Report further requests that the Corps of Engineers prepare and submit a report "on measures that have been taken, and any agreements reached, to assure that the quality of water supplied to the Park will not deteriorate****."

The objective of this report is to provide information that will enable the National Park Service and Corps of Engineers to establish measures jointly that will provide for and ensure the maintenance of water quality adequate to prevent damage or deterioration of the park ecosystem.

The pertinent part of the Senate report is included in the appendix.

SCOPE

The report concerns that part of Everglades National Park receiving water from the Central and Southern Florida Flood Control Project. Data and discussion, therefore, apply to the Kissimmee-Okeechobee-Everglades drainage system and to water quality conditions of Everglades National Park. The principal drainageways in the park, Shark River Slough and Taylor Slough, are shown on Figure 1.

The effect of the quality of water from Big Cypress Swamp on the western part of the park is discussed in the Leopold Report (Reference 1). Data on Big Cypress are few and recent, but do suggest that water quality in this drainage is little impaired at this time (References 2,3,4 and 5). It is important to stress, however, that the maintenance of the present high quality of water in the Big Cypress is seriously threatened by the potential for urban, agricultural and industrial developments. Without prompt protective steps, drainage works will destroy the sensitive ecosystem and subsequently degrade the water quality in the western portion of the park. Water quality in the estuarine and inshore marine areas of the park is considered in the report only as it is affected by upland flow.

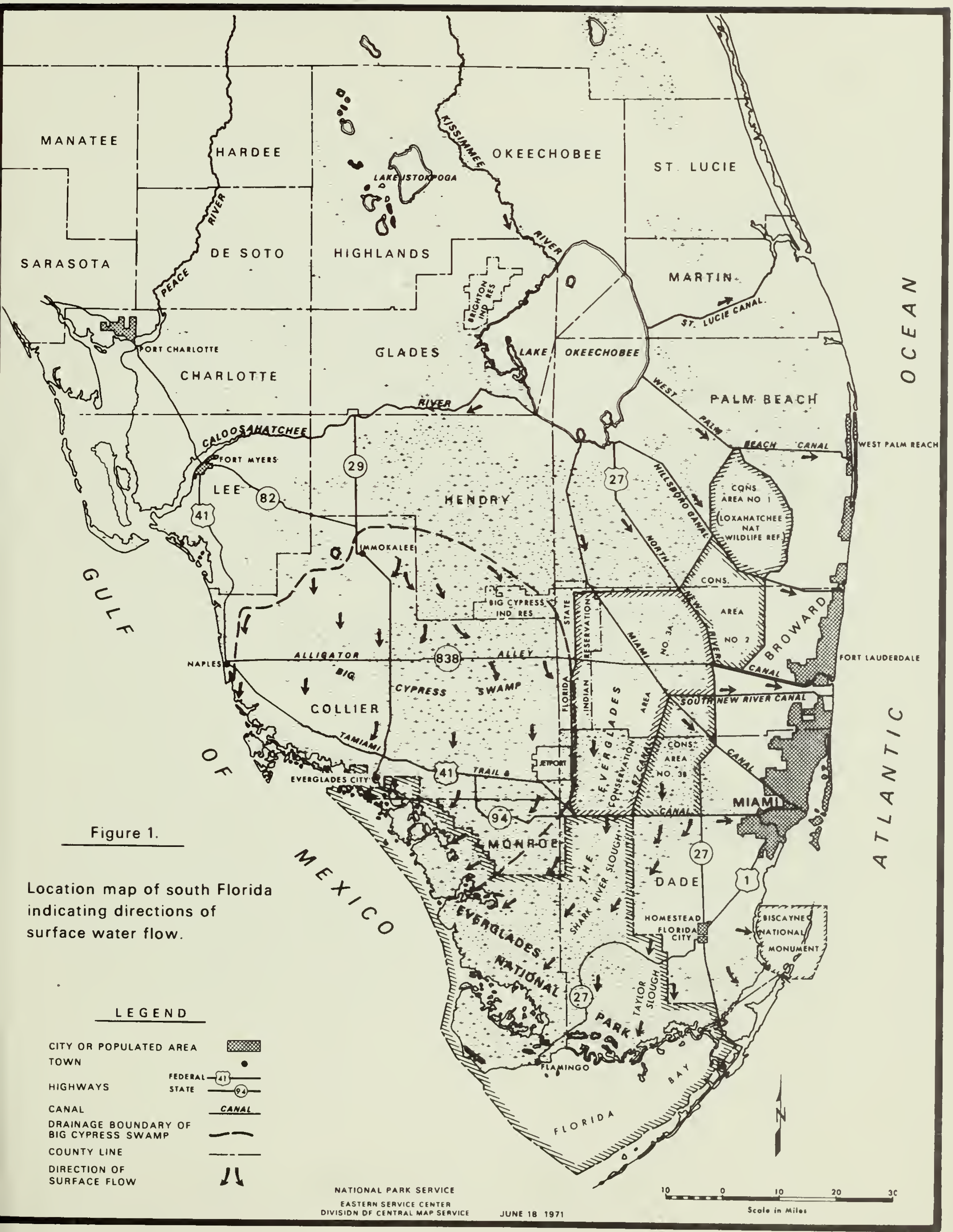

Figure 1.

Location map of south Florida indicating directions of surface water flow.

WATER QUALITY RECORDS

Most of the data on the quality of surface and ground water in the Kissimmee-Okeechobee-Everglades drainage system are from samplings by the U.S. Geological Survey, analyses of which are published in its annual reviews of water resources data for Florida. Some stations extend back to the early 1940's. Other agencies such as the Corps of Engineers, the predecessor agencies to the Water Quality Office of the Environmental Protection Agency, agencies of the State of Florida and several universities have also collected water quality data but this information was either not readily available or not applicable to the purposes of this report. The data should, nonetheless, be compiled for use in a general study of overall conditions in central and south Florida.

The Geological Survey water quality program in Everglades National Park began in 1959, and some of these data have been discussed in various publications and reports in addition to appearing in the annual statewide reviews. Long-term stations have 5 or more years of sampling records; short-term stations have less than 5 years of records and may include as little as a single sampling. These water quality sampling

stations in the Everglades drainage basin are distributed as follows:

		Number of Long-Term Stations		Number of Short-Term Stations
Kissimmee-Lake Okeechobee		12		74
Conservation Areas		8		49
Everglades National Park				
Interior	8		0	
Estuarine	5	13	10	10
Total		33		133

The Survey made all the analyses using its standard water quality laboratory program. Dissolved minerals and several of the physical characteristics were analyzed for all stations then in existence beginning in the 1940's. Sampling at some of the Survey's long-term stations has been considerably expanded beginning in 1960, in response to the markedly increased concern about unnatural enrichment from excessive nutrients, and the toxicity and biological magnification of heavy metals and chlorinated hydrocarbon insecticides.* Sampling analyses are being carried out in Loxahatchee National Wildlife Refuge, which is Conservation Area No. 1 of the Central and Southern Florida Flood Control Project, and in the Everglades National Park. The analyses include determinations of pesticide levels in the water, sediments, several plant species, and animals at a number of trophic levels. The examinations of animal tissues provide a measure of the biological magnification of toxic materials in Everglades communities. Concurrently, other data on pesticide residues in specific biological materials are being collected by the National Park Service's research biologists.

*See appendix for comments on use of terms.

Samples are being analyzed for the following:

Aldrin	Dieldrin	Nitrite
Alkalinity	Dissolved oxygen	Organic nitrogen
Aluminum	Endrin	Orthophosphate
Ammonium	Fluoride	pH
Arsenic	Hardness	Potassium
Bicarbonate	Heptachlor	Silica
Boron	Heptachlor epoxide	Sodium
Bromine	Free carbon dioxide	Specific conductance
Calcium	Iodine	Strontium
Carbonate	Iron	Sulfate
Chloride	Lead	Tannin & Lignin
Chromium	Lindane	Temperature
Coliform bacteria	Lithium	Total dissolved solids
Color	Magnesium	Total organic carbon
Copper	Mercury	Total phosphorus
DDD	Nickel	Turbidity
DDE	Nitrate	Zinc
DDT		

Data from 29 of the long-term water quality stations were entered into a digital computer program to provide statistical summaries and tabulations. These stations present information on a regional basis for the Kissimmee-Okeechobee-Everglades drainage system and serve as the major source of information for judging water quality conditions. The selected stations are the first twenty-nine listed in Table 1. All stations referred to in this report are listed in Table 1 and their locations are shown on Figure 2.

Table 1. Water-Quality Index Stations in the Kissimmee-Okeechobee-Everglades Region

Station	Computer Identification Symbol	Location
1.	02-2725.00	Kissimmee River near Basinger
2.	02-2729.90	Kissimmee River near Okeechobee
3.	02-2730.00	Kissimmee River at S-65E near Okeechobee
4.	02-2780.00	West Palm Beach Canal at HGS-5 at Canal Point
5.	02-2764.16	Lake Okeechobee at Pahokee
6.	02-2920.00	Caloosahatchee Canal at Moore Haven
7.	02-2805.00	Hillsboro Canal below HGS-4 near South Bay
8.	02-2835.00	North New River Canal below HGS-4 near South Bay
9.	02-2864.00	Miami Canal at HGS-3 and S-3 at Lake Harbor
10.	02-2812.00	Hillsboro Canal at S-6 near Shawano
11.	02-2813.00	Hillsboro Canal at S-39 near Deerfield Beach
12.	02-2845.20	Diversion Canal at S-143 near Andytown
13.	02-2853.99	South New River Canal above S-9 near Davie
14.	02-2854.00	South New River Canal below S-9 near Davie
15.	02-2871.05	Miami Canal at S-31 near Miami
16.	02-2873.95	Miami Canal east of L-30 near Miami
17.	02-2888.00	Tamiami Canal Outlets, Monroe to Carnestown
18.	02-2888.04	Tamiami Canal at Bridge 86 near Ochopee
19.	02-2890.30	Tamiami Canal above S-12-B near Miami
20.	02-2890.31	Tamiami Canal below S-12-B near Miami
21	02-2890.60	Tamiami Canal at Bridge 45 near Miami
22.	02-2908.12	Alligator Hole at Cottonmouth Camp near Homestead
23.	02-2908.13	Open Glades near Cottonmouth Camp near Homestead
24.	02-2908.15	Everglades P-33 near Homestead
25.	02-2908.70	Everglades P-34 near Homestead
26.	02-2908.30	Everglades P-35 near Homestead
27.	02-2908.00	Taylor Slough near Homestead
28.	02-2908.20	Everglades P-38 near Homestead
29.	02-2908.10	Everglades P-37 near Homestead
30.	02-2908.28	Everglades P-36 near Homestead
31.	02-2908.58	Shark River at Ponce de Leon Bay near Homestead
32.	unassigned	Alligator Hole at Taylor Slough near Homestead
33.	02-2907.98	Taylor River near Florida City
34.	02-2907.96	Little Madeira Bay near Key Largo
35.	unassigned	Canal at L-67 above S-12E near Miami
36.	02-2785.00	Everglades below S-5A near Delray Beach
37.	02-2812.95	Everglades Station 1-15
38.	02-2784.50	West Palm Beach Canal above S-5A
39.	02-2785.50	Levee 8 Canal at S-5A
40.	02-2812.74	Levee 40 Canal at Everglades Station 1-5
41.	02-2812.78	Everglades Station 1-7
42.	02-2812.90	Everglades Station 1-9

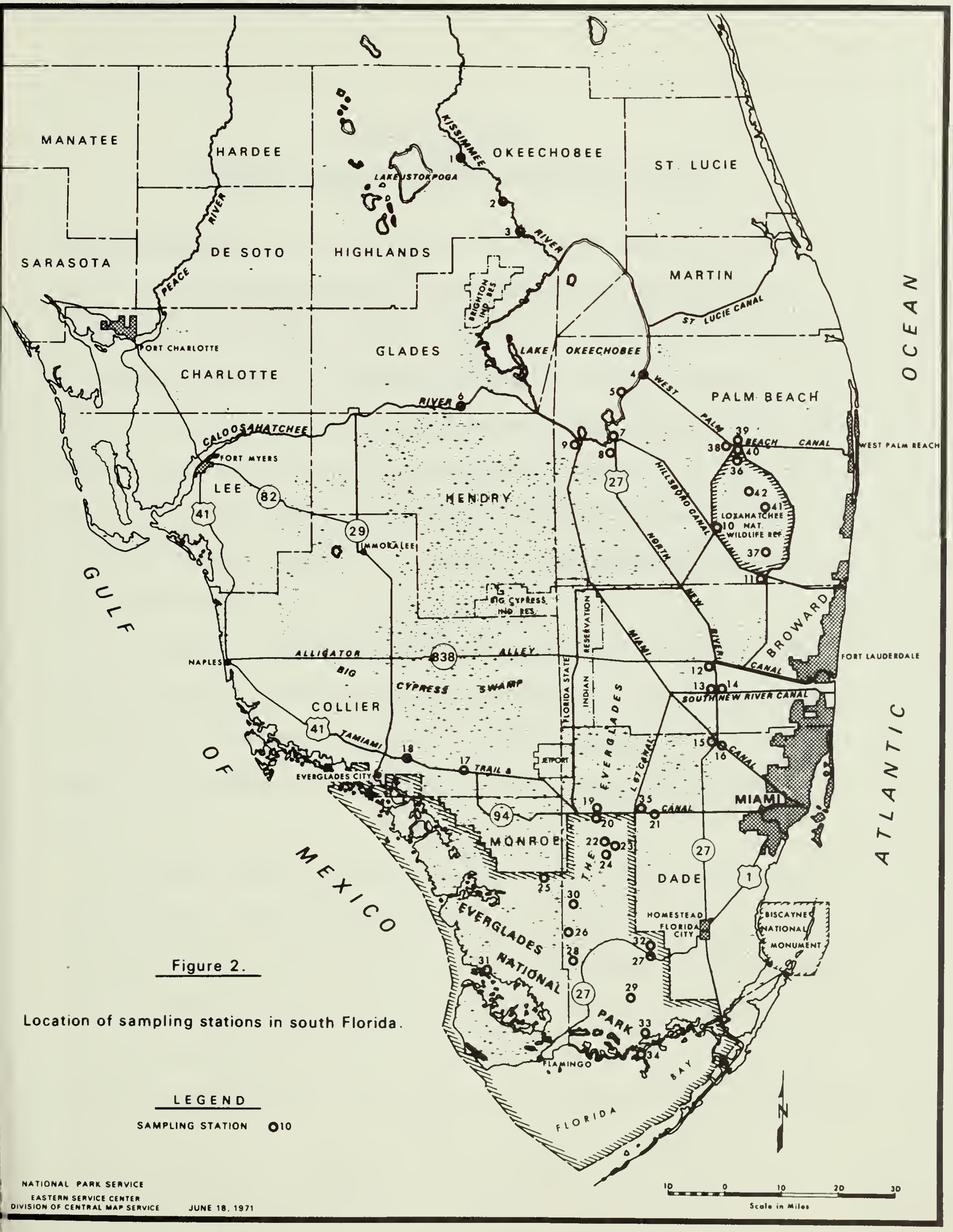

Figure 2.

Location of sampling stations in south Florida.

QUALITY OF WATER IN THE KISSIMMEE-OKEECHOBEE-EVERGLADES DRAINAGE SYSTEM

Dissolved Minerals. As an indication of the quality of the fresh water in the Kissimmee-Okeechobee-Everglades system, the range and median values of nitrate, sulfate, calcium, dissolved solids and iron at selected stations were compared with median values of surface waters of the United States based on analyses made in the early 1900's when the streams were relatively unpolluted (Reference 6). These five constituents become pollutants at excessive concentrations altering the habitat so that trash fish adaptable to the degraded environment soon replace the mixed fish assemblage.

The ranges of values and the median concentration of these five particular chemical constituents were calculated for the Tamiami Canal, the marshes in the canals adjacent to Loxahatchee National Wildlife Refuge, and the marshes in the refuge. These values are listed in Table 2.

The median values for nitrate, sulfate, and iron in the marshes and inland canals were comparable with those of the surface waters of the United States. The marshes and canals in southeast Florida generally contain a healthy mixture of bass, bream, and other game fish along with gizzard shad, gar, and bowfin. Of the five constituents, only levels for calcium and dissolved solids are higher in the Everglades marshes and

Table 2. A comparison of pre-1924 median values of United States surface waters with waters of the Everglades National Park, Loxahatchee National Wildlife Refuge and nearby canals that support a mixed fish fauna.

	pre-1924 U.S. Waters	Everglades National Park						Loxahatchee National Wildlife Refuge and nearby canals			
		Tamiami Canal 2/		Shark River Slough 3/		Taylor Slough 4/		Canals 5/		Marshlands 6/	
	Median 1/ (mg/1)	Range (mg/1)	Median (mg/1)	Range (mg/1)	Median (mg/1)	Range (mg/1)	Median (mg/1)	Range (mg/1)	Median (mg/1)	Range (mg/1)	Median (mg/1)
Nitrates	0.9	0- 17	0.4	0- 79	0.7	0- 74	.5	0 - 34	0.3	0 - 10	0.5
Sulfates	32	0- 66	3.6	0- 77	0.4	0- 62	.4	1.6- 138	38	0 - 7	1.0
Calcium	28	7-133	60	35-173	54	34-110	60	8.8- 133	62	2.8- 34	7.6
Iron	0.3	0- 0.6	0.02	0- 0.87	0.03	0- 0.5	0.01	0 - 0.9	0.04	0 - 0.17	0.03
Dissolved solids	169	77-402	193	114-462	206	102-370	182	43 -1330	425	23 -149	53

1/ From Hart, 1945 (reference 6)
2/ Tamiami Canal: Stations 18, 19 and 21, Oct. 20, 1955 to Sept. 30, 1970 (172 water samples)
3/ Shark River Slough: Stations 22, 23, 24 and 25, Dec. 24, 1959 to Sept. 30, 1970 (116 water samples)
4/ Taylor Slough: Station 27, Dec. 14, 1960 to Sept. 30, 1970 (47 water samples)
5/ Canals adjacent to Loxahatchee: Stations 10, 11, 38, 39 and 40, Sept. 5, 1956 to Aug. 19, 1969 (208 water samples)
6/ Marshlands within Loxahatchee: Stations 41 and 42, June 16, 1955 to July 2, 1964 (98 water samples)

canals than in the United States waters. The higher values of calcium and dissolved solids are due to the interrelationship of ground and surface water in the Everglades. Water on the surface, in the peat soils, and in the underlying limestone are parts of the same continuous water body. Much of the water flowing through the glades has passed through the limestone, where it picks up the readily soluble calcium, and eventually mingles with the surface water. Ground water in the basin is generally higher in calcium and other elements than is surface water.

A small but clear upward trend in dissolved solids concentrations, beginning about 1959, has been observed at Tamiami Canal at Bridge 45, Station 21, and at Everglades P-33, Station 24. Prior to 1959, the concentration was generally about 200 mg/l*, whereas since then it generally is more. The values for calcium show a similar trend. These higher values are believed due to excavations and other man-caused disturbances in the limestone.

Dissolved solids in the canals are noticeably higher than in adjacent sloughs and marshes. The median value for dissolved solids in canals at Loxahatchee National Wildlife Refuge is 425 mg/l, but in the marshes within the refuge, it is only 53 mg/l, as shown in Table 2. In the urbanized coastal areas, the water quality in most canals is poorer than in the canals farther west as at Loxahatchee, with the consequence that the coastal canals there contain fishes and other biota that are less desirable. The poor conditions in the coastal canals in Dade County are discussed in reference 7.

*See appendix for comments on units.

It will be noted that the median value for sulfate in the canals adjacent to Loxahatchee is above the median for the United States waters and is also higher than other values in the tables. A possible source of this excess sulfate is fertilizers from adjacent agricultural areas. The absence of excess sulfate in the other areas is assumed due to assimilation by the ecosystem or possibly to dilution.

The values for dissolved solids appear to be the best single reliable index of water quality. "In the natural waters, dissolved solids consist mainly of carbonates, bicarbonates, chlorides, sulfates, phosphates and possibly nitrates of calcium, magnesium, sodium, and potassium, with traces of iron, manganese and other substances." (Reference 8). The mineral content of natural water is raised by the addition of urban wastes, such as sewage, chemical wastes from industry, or drainage from agricultural lands. As this indigenous ecosystem is a response to and is in consonance with the mineral content of the natural water, it is the addition of these latter nutrients which encourages nuisance plant growths.

The record of dissolved solids has been examined at the index stations in the Kissimmee-Okeechobee-Everglades basin to determine whether seasonal and long-term ranges are being maintained. The data indicate that dissolved solids generally are increasing throughout the basin. Values for dissolved solids for Lake Okeechobee water

rose from 190 mg/l in 1940/41 to 260 mg/l in 1969/70, with concurrent increase in calcium, magnesium, sodium, chloride, sulfate and bicarbonate. For water in Shark River Slough collected at Station 24, the dissolved solids ranged from 129 to 162 mg/l in 1960/61 and increased to a range of 221 to 309 mg/l in 1968/69. On the other hand, values for dissolved solids did not show a similar increase for these same years in Everglades National Park at Taylor Slough, Station 27, and in the sawgrass marsh, Station 25.

In view of this, the recommendation of the National Technical Advisory Committee to the Secretary of the Interior, 1968, on Water Quality Criteria, warrants consideration in setting water quality standards for dissolved solids (Reference 9). The Committee held, "a slight increase in the total dissolved materials may be tolerable to a certain extent but should not be increased to more than one-third of the concentration that is characteristic of the natural condition of the water where diversified animal populations are to be protected."

Nutrients. National Park Service scientists believe that maintenance of historic nutrient levels is crucial to the preservation of the present ecosystems intact as well as the biological well-being of the park.

Data on background levels of nutrients in the park are limited to values for nitrate and orthophosphate. Measurements of ammonia

nitrogen, nitrite, organic nitrogen, total phosphorus and total organic carbon at several stations in the park have been few and have been collected for only the past two years. The Leopold Report indicates that current ranges in background levels of total nitrogen (N) and total phosphorus (P) in the northern part of the park are 1.0-5.0 mg/l and 0.01-0.50 mg/l, respectively (Reference 1). Analysis for total N and total P were not made in the basin until recently. Mean values for nitrate, and orthophosphate are 0.6 mg/l, and 0.02 mg/l, respectively, in the park. (See Table 7.)

Although not precisely comparable, values for nitrate and orthophosphate can provide a representative measure of total N and total P. There are several methods for reporting N and P. In the data used in preparation of this report, all forms of N were reported separately and all forms of phosphate were reported as orthophosphate.

Median levels for calcium, bicarbonate, nitrate, and orthophosphate at all stations in the park, as shown in Table 3, are low relative to water in the Okeechobee-upper Everglades area. Variations in concentrations have occurred in the park and appear to be seasonal but no significant trend has been determined since 1959, when records began.

The plan recommended in the Corps of Engineers survey - review report on water resources for central and southern Florida, authorized by Congress in 1958, includes provision for pumping water from

Table 3. Median values for selected quality characteristics in the Kissimmee-Okeechobee-Everglades drainage

	Water Quality Index Stations 1/	Calcium (mg/l)	Bicarbonate (mg/l)	Nitrate 2/ (mg/l)	Phosphate 3/ (mg/l)	Specific conductance (micromhos at 25°C)
Kissimmee	1.	9	19	0.2	0.02	112
	2.	6	17	0.2	*	81
	3.	18	46	0.4	0.11	172
Okeechobee-Upper Everglades	4.	47	156	0.5	0.07	501
	5.	50	165	0.4	0.02	521
	6.	41	120	0.3	0.06	374
	7.	82	269	1.7	0.29	874
	8.	81	296	1.1	0.00	875
	9.	55	185	0.8	0.03	624
	10.	68	255	1.6	*	781
	11.	59	242	0.0	0.05	802
	12.	58	250	0.2	0.03	738
	13.	87	281	0.9	*	567
	14.	90	313	0.8	*	710
	15.	71	271	0.3	0.02	663
	16.	74	256	0.5	0.09	517
	17.	64	200	0.9	*	400
	18.	64	205	0.3	0.03	342
	19.	59	190	0.6	*	365
	20.	50	170	0.4	*	350
	21.	56	168	0.5	*	337
Everglades National Park	22.	48	170	0.8	0.02	358
	23.	50	177	0.5	0.02	385
	24.	52	170	0.9	0.01	400
	25.	60	182	0.3	0.02	327
	26.	51	175	0.8	0.04	437
	27.	57	180	0.4	0.02	340
	28.	56	140	0.3	0.00	445
	29.	57	175	0.3	0.00	460

1/ See Table 1, and Figure 2 for locations

2/ Nitrate only. Excludes other forms of nitrogen

3/ Orthophosphate includes meta, para-, and orthophosphate all reported as orthophosphates

* Insufficient data

east coast canals back to the conservation areas (Reference 10). The water in the canals to be backpumped contains much larger concentrations of insecticides and nutrients than are found in the conservation areas and the park. Water draining to the canals during the backpumping can be expected to be high in fertilizers, urban wastes and insecticides. Even slight increases in some plant nutrients will increase undesirable algae and replace algae normally found in the Everglades water and in its algal mats. Such alteration of the organisms at the bottom of the food chain results in changes in the species and relative numbers of aquatic animals that comprise the Everglades biota.

Provision must be made for removal of excess nutrients. This may require chemical or biological treatment of the the water to alter the chemical composition of the nutrients to acceptable forms. Rapid oxidation by physical or biological means may limit the amount of the nutrients being pumped into the conservation areas. Spreading the water in the conservation areas may enable biological uptake of the nutrients within the capability of the natural system. It may also be necessary to waste some of the more highly polluted water to the sea.

In 1970, the Cental and Southern Florida Flood Control District had the Geological Survey start a study of the quality of water back-pumped to Conservation Area No. 3A from Pump Station S-9 at the South New River Canal. The objective is to evaluate the ecological consequences of backpumping. Considerable experimentation with varying rates of pumping will be tried before a plan of operation can be devised.

Information that would permit the setting of a maximum allowable increase in nutrients such that no disturbance would be caused to the Everglades ecosystem will require additional research. In the interim, the recommendation of the Public Water Supply Subcommittee of the Technical Advisory Committee should be followed, namely, that allowable amounts of total P not exceed 0.05 mg/l where streams enter lakes or reservoirs. The Subcommittee states "Fifty micrograms per liter of total phosphates (as P) would probably restrict noxious aquatic plant growths in flowing waters and in some standing waters." A similar recommendation is not made for nitrogen, but the Subcommittee on Water Quality Criteria for Fish, Other Aquatic Life, and Wildlife recommends "The naturally occurring ratios and amounts of nitrogen (particularly NO_3 and NH_4) to total phosphorus should not be radically changed by the addition of materials." (Reference 9).

Trace Elements and Heavy Metals. All living things require minute quantities of certain chemical elements for their functioning. These elements together with larger amounts of nitrogen, phosphorus, calcium, magnesium, potassium and sulfur are the nutrients which are essential for growth and reproduction. They include aluminum, boron, chlorine, cobalt, copper, iron, manganese, molybdenum, silicon, vanadium and zinc. The minimum requirement for a specific element varies with the species and is poorly understood for nondomestic plants and animals. For example, one literature researcher found that the minimum iron requirement for algae ranges from 0.00065 to 6.0 mg/l and he states, "The

uncertainty as to what concentrations are essential is shown*** by the wide range of minimum requirements. ***when concentrations exceeded these values, nuisance conditions could be expected." (Reference 11).

Heavy metals include some trace elements, as well as arsenic, cadmium, chromium, lead and mercury. These latter metals are toxic at varying concentrations. Trace element heavy metals become toxic at above normal concentrations. At lower levels individual metals become toxic through synergism. For example, "Cadmium acts synergistically with other substances to increase toxicity. Cadmium concentrations of 0.03 mg/l in combination with 0.15 mg/l of zinc***caused mortality of salmon fry." (Reference 8). Trace amounts of lead, zinc, manganese, strontium, boron, and bromine have been found at Everglades P-33, Station 24, and these values, as shown in Table 4, are representative of other stations in the park. Traces of mercury and arsenic have been found in water from some canals in Broward County and elsewhere in southeast Florida, but not inside the park.

Somewhat greater than normal concentrations of calcium and magnesium influence heavy metal toxicity. It would appear, therefore, that setting safe levels for heavy metals depends on calcium and magnesium concentrations. The effects of heavy metals on the biota of the park have yet to be evaluated.

The toxicity levels for heavy metals must be evaluated to provide recommendations for limits of these constituents. Nutrient budgets and cycles in the aquatic ecosystems must be determined and desirable ranges for trace elements defined.

Table 4. Trace elements and heavy metals at Everglades P-33, Station 24, Shark River Slough, in mg/l

Date of Collection	ALUMINUM	ARSENIC	BORON	BROMINE	CHROMIUM	COPPER	IODINE	LEAD	LITHIUM	MANGANESE	STRONTIUM	ZINC
08-31-67	0.20	0.01	0.12	*	0.00	0.00	*	0.00	0.00		0.39	0.02
10-11-67	0.20	0.00	0.05	*	0.00	0.00	*	0.01	0.00	0.02	0.40	0.05
11-10-67	0.00	0.00	0.05	*	0.00	0.00	*	0.00	0.00	0.01	0.46	0.01
01-25-68	0.20	0.00	0.07	*	0.00	0.01	*	0.01	0.00	0.01	0.60	0.04
03-08-68	0.30	0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.65	0.04
05-30-68	0.30	0.00	0.11	*	0.01	0.00	*	0.00	0.00	*	0.34	0.01
08-06-68	*	*	*	*	0.00	0.00	*	0.01	0.00	*	*	0.01
10-03-68	0.15	0.00	0.58	*	0.00	0.00	*	0.00	0.00	*	0.75	0.00
11-26-68	0.03	0.13	0.05	*	0.01	0.00	*	0.01	0.00	0.00	0.60	0.01
02-17-69	0.30	0.00	0.02	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.51	0.05
05-06-69	0.15	0.00	0.08	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.89	0.02
04-06-70	*	0.00	*	0.66	0.00	0.00	0.00	0.01	0.00	0.02	0.89	0.02

* No data

Dissolved Oxygen. As water levels drop in the Everglades, the sawgrass marshes dry and most fauna move to or into the canals, wet prairies, and alligator holes. The resulting cconcentrations of aquatic organisms often deplete the available oxygen in these water bodies. Depletion increases throughout the night when absence of sunlight and greatly reduced photosynthesis cause the aquatic plants to cease oxygen production. Biological consumption and the oxidation of organic matter are parts of a continuous process, which depends on the dissolved oxygen for its continuation. The dissolved oxygen concentration is affected by a number of physical and chemical characteristics of the water, and as the water levels decline, competition among organisms for oxygen increases and is especially critical at night. The seasonal recession of the water level in the Everglades and the diurnal cycle are the dominant factors that initiate the physical, chemical and biological changes which collectively result in the depletion of dissolved oxygen.

Dissolved oxygen (DO) was determined at two stations at Cottonmouth Camp, in Everglades National Park: Station 22, in the alligator hole; and, Station 23, in the sawgrass marsh. These determinations were made hourly or bihourly, for a 24-hour period about once each month, from April 1965 to June 1968. Figure 3 graphically illustrates the results of this series of measurements.

During high-water periods (Figure 3A, and 3B), DO concentrations were similar in the sawgrass marsh and the alligator hole, always being above 3 mg/l with a peak of nearly 9 mg/l in mid- or late afternoon.

When the water level fell below the ground surface, the sawgrass marshes became isolated from the alligator hole and some organisms moved into burrows as shown in Figure 3C. Some of the remaining animals, particularly large fishes such as gar and bream, had by then moved into the deeper alligator hole that still contained water as indicated in Figure 3D.

During the low water periods, the DO remained below 2 mg/l during most of each day, resulting in a mortality of susceptible aquatic animals typified by the centrarchid fishes such as bass and bream. Figure 3C and 3D shows no measurable DO in the sawgrass marsh because no water was present; the measurable DO in the alligator hole at that time was less than 3 mg/l as shown in Figure 3D.

The respiratory activity of many fishes and other aquatic animals begins to be severely affected as the DO falls below 3 mg/l, especially in subtropical waters such as are found in the Everglades. Few fishes can exist overnight at DO levels below 1 mg/l. Although DO levels have fallen below 4.0 mg/l during low water periods within the park without mortality of aquatic fauna having occurred, depression below 4.0 mg/l generally has induced conditions of stress.

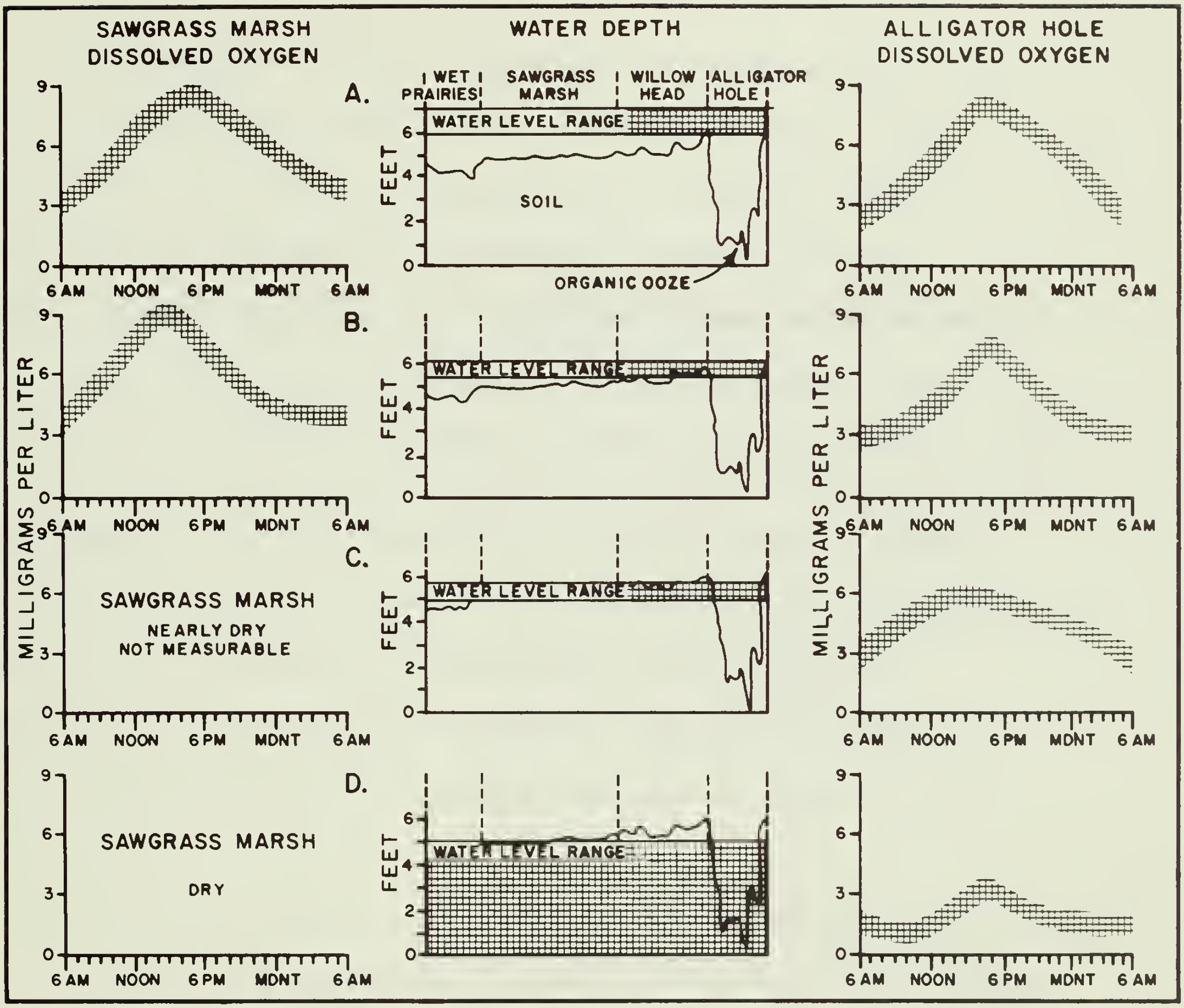

Figure 3. Relationship between fluctuations in dissolved oxygen and water levels in Shark River Slough.

In the absence of definitive research conclusions on DO levels for Everglades waters, the Florida State Rules on Water Pollution should be used as a standard until a specific determination based on research is established. For DO, the rule requires that the DO shall not be artifically depressed below the values of 4.0 mg/l, unless background information indicates prior existence under unpolluted conditions of lower values (Reference 12).

Insecticides. The three year period of sampling for chlorinated hydrocarbons has been too short to show any clear trends of change. Furthermore, the intensity of sampling has been inadequate to support firm conclusions on the seasonal or geographic patterns of insecticide pollution within the park, but data in Table 5 suggest that:

1. Residues of DDT in most biological materials sampled are higher in the dry season, normally winter and spring, than in the wet season, normally summer and fall.
2. Residue concentrations at all trophic levels appear to be higher at the more northern stations in the Shark River Slough and Taylor Slough drainages, and decrease progressively at successive downstream stations.
3. The insecticide levels in Taylor Slough drainage are somewhat higher than in the Shark River Slough.

Table 5. Summary of DDT + DDD + DDE concentrations in selected Everglades ecosystem components

Station		Surface Water Wet	Surface Water Dry	Submerged Soil Wet	Submerged Soil Dry	Algae Wet	Algae Dry	Aquatic Plants Wet	Aquatic Plants Dry	Invertebrates Wet	Invertebrates Dry	Small Fish Wet	Small Fish Dry
Loxahatchee	36	0.04	*	46.8	*	*	*	6.5	*	0.00	*	368.0	*
								9.0		37.0			
	37	0.01	*	8.6	*	*	*	6.0	*	14.0	*	204.0	*
								27.5					
Shark River Slough	35	0.03	*	40.0	37.8	*	*	*	*	*	*	*	*
				0.00									
	24	0.01	0.03	3.9	25.1	3.0	33.6	2.0	6.5	*	0.00	57.3	538
							3.4		0.00				
									14.9				
									8.0				
	30	0.00	0.00	48.8	11.3	1.5	4.1	3.0	9.0	*	*	188.0	730
								3.5	15.9				
	26	0.03	0.01	3.0	4.1	*	*	*	2.1	*	133.0	*	808
			0.00						9.6				
	31	0.01	0.01	2.8	3.4	*	*	*	*	*	0.00	*	*
Taylor Slough	27	0.02	0.04	5.0	44.3	7.0	4.3	21.0	9.6	*	*	184.0	848
		0.03	0.00	4.1					11.6			272.0	**2.0
	32	*	*	3.2	14.1	*	*	*	*	*	*	*	*
	33	*	*	*	*	0.6	4.8	0.00	11.7	*	27.0	27.0	16.0
								0.00			0.00	0.00	
								3.7			0.00	0.00	
	34	*	0.02	*	0.00	*	*	*	*	*	*	*	*

* Data are absent
**Dieldrin and lindane

Data on biological magnification of insecticides in the Everglades ecosystem are sketchy, but these data appear to show a consistent pattern of increases at each trophic level. DDT and its metabolites are the major chlorinated hydrocarbon insecticides present and these are found throughout the park in concentrations that are significant biologically at upper trophic levels.

Table 6 indicates the orders of magnitude for levels of biological accumulation of the DDT family in ecosystem components of Everglades National Park and Loxahatchee National Wildlife Refuge. Data evaluation indicates that for each ppb residue found in the ground or surface water, ten times (10 ppb) that amount is found in the rain and 100 times (100 ppb) is found in the vascular plants. Other relative orders are shown for other components (Reference 13).

A measure of the relative level and ecological impact are suggested in the findings of a 1970 study, which reported that six bald eagle eggs from Florida Bay showed a mean value of 11,770 ppb, within a range of 4,790 to 28,140 ppb for residues of DDT and its metabolites (Reference 14). Data from other areas outside the park suggest that critical eggshell thinning and reproductive failure in bald eagles can be anticipated when DDT residues in eggs reach about 20,000 ppb. Although chlorinated hydrocarbon insecticides other than DDT have seldom been detected in sampling at the lower trophic levels, residues of several additional compounds have

Table 6. Generalized scheme of biological accumulation of the DDT family in Everglades National Park and Loxahatchee National Wildlife Refuge.

Environmental component	Concentration of DDT+DDD+DDE Parts per Billion X = digit	Times Greater than Surface Water 1/
Water: Surface	.0X	1
Ground (in surface aquifer)	.0X	1
Rain	.X	10
Everglades vascular plants (producer)	X.	100
Everglades submerged soils	X0.	1,000
Everglades algal mats or periphyton (producer)	X0.	1,000
Everglades crustaceans (omnivores)	X0.	1,000
Everglades marsh fishes (omnivores and primary carnivores)	X00.	10,000
Everglades alligators (higher carnivore)	X00.	10,000
Eagle and Everglade Kite (higher carnivore)	X000.	100,000

Adapted from "Organochlorine insecticide residues in Everglades National Park and Loxahatchee National Wildlife Refuge, Florida," by M. C. Kolipinski, A. L. Higer, and M. L. Yates, Pesticide Monitoring Journal, (In press).

1/ For example, rain contains 10 times the amount of DDT+DDD+DDE found in surface water, and the alligators contain 10,000 times this amount. This should not be interpreted that insecticides disappear from the system when rain becomes surface or ground water. This reduction is due to deposition in sediments and uptake by biological organisms.

been reported in significant quantities at upper levels of food chains. The same sample of bald eagle eggs showed a mean value of 210 ppb within a range of 110 to 280 ppb for dieldrin and 20 ppb for heptachlor epoxide.

It is clear that residues of chlorinated hydrocarbon insecticides near or below the technological limits of detection in water are magnified biologically to concentrations that are critical to all park populations of fish-eating birds. The only practical control is by the elimination of use of chlorinated hydrocarbon insecticides in the Everglades drainage basin. There is no acceptable level of these materials in water delivered to the park.

Industrial Pollutants. Specific examinations for industrial wastes have not been made except for heavy metals. However, routine examinations for chlorinated hydrocarbons are being monitored for polychlorinated biphenyls (PCB's). Little is known of the extent or effects of PCB's on the Everglades ecosystem. These compounds, used as plasticizers and in insecticides, business forms, floor tiles and many other products, although commercially available for more than 40 years, and, although undoubtedly present, were not detected in the environment until 1966. The discovery was accidental and was first noted in connection with chlorinated hydrocarbon analyses. PCB's have since been found in many parts of the world, including Antarctica. The relatively few experiments which have been made indicate that PCB's act similarly to DDT and its metabolites, offering the same hazards. While in some cases they are not as toxic as the

other chlorinated hydrocarbons, they appear to be highly toxic to shellfish, oysters, and shrimp. A 100 percent mortality of juvenile pink shrimp exposed to 100 ppb PCB for 48 hours has been reported (Reference 15). Considerable research is necessary before the full significance of PCB's on the environment will be known. Because the few experiments thus far conducted have shown both acute and chronic toxicity to fish and wildlife types found in Everglades National Park, the same conclusion must be reached for PCB's as for the other chlorinated hydrocarbons. There is no acceptable level of these materials in water delivered to the park.

Temperature. In the Everglades, aquatic organisms are under increasing stress in the summer months as water temperatures approach lethal levels. An organism might endure a high temperature of 35C for a few hours but not for a few days. In the fresh water marshes of the park, temperatures can attain 35C in the afternoon hours of the hotter days of the year, and on particularly hot days in August, temperatures of 38C have occasionally been reached. Water temperatures have been measured in the park, but these have been in daylight hours and only for the surface layer of the water. Depth of water and shading provided by vegetation affect water temperature, so that unseasonal changes in water supplies and vegetation in the areas immediately adjacent to the park are seen as factors affecting the viability of the park. As water temperature is seen to vary with water depth, and as increased temperatures can stimulate molecular activity of chemicals constituents in the water, water depth may be a critical factor in yet

unsuspected areas. To maintain normal water temperatures, delivery rates and quality of the water must approximate natural conditions, and no addition of heat should be permitted which may influence the temperature of the water entering the park.

SUMMARY AND CONCLUSIONS

Conclusions are tentative and longer observations and study may alter them. Water in Everglades National Park supports a natural mixed fish fauna and is acceptable when compared with the quality of the surface waters of the United States in the early 1900's although it exceeds several quality parameters. Except for chlorinated hydrocarbons, there is little indication of large scale deterioration, despite a widening of the range of values in recent years. Upward trends in some constituents are becoming apparent, though the rates of change are low. Altogether, the water coming to and in the park is good and is not intolerably different from probable historical quality.

Chlorinated hydrocarbons were never part of the historical water quality. Despite all precautions taken to protect the water supply, both as to quantity and quality, the effort may be meaningless if the ecosystem is irreversibly altered due to the pernicious effects of biologically concentrated chlorinated hydrocarbons. In any amounts, their presence is a threat to the park.

The same must be said of other organic compounds, heavy metals, and certain of the trace elements. Any degradation of water quality may well spell the end of the Everglades ecosystem. Authorized changes in water quality must be based on study which can enable safe deviations from historical or present quality.

The report does not discuss the quality aspect of dry season versus wet season conditions. The investigators have, however, found in plotting thousands of bits of data that larger concentrations of individual chemical constituents occur in dry season samples than in wet season samples. That the concentrations are greater when less water is available is obvious but not as important as the observation that a continuous but seasonally varying supply maintains the historical quality of the water

Tentative water quality standards are listed in Table 7. These standards represent average values of the data from stations 22, 23, 25, and 27. Where data are limited or are otherwise inconclusive, the standard shown in Table 7 has been selected from other sources (Reference 16). Fifty and 95 percentiles for stations 22 through 29 are given in Table 8 and frequency distributions are shown as bar graphs in Figures 4, 5 and 6, in the appendix.

Table 7. Surface water criteria in Shark River Slough and Taylor Slough, Everglades National Park

Constituent or characteristic	Mean value* (50 percent) (mg/l)	Upper limit* (95 percent) (mg/l)
Physical:		
Color (color units)	26	58
Temperature	**	**
Turbidity	10	23
Inorganic Chemicals:		
Bicarbonate	169	219
Calcium	54	77
Chloride	26	46
Dissolved oxygen	**	**
Fluoride	.2	.3
Dissolved iron	.02	.3
Magnesium	4.6	7.8
Nitrate (as NO_3)	.6	2.6
pH (laboratory)	7.5	8.1
Orthophosphate (as PO_4)	**	**
Potassium	.6	2.0
Silica	3.1	13
Sodium	18	30
Sulfate	.4	6.5
Total dissolved solids	198	277
Heavy metals & trace elements	**	**
Organic Chemicals:		
Chlorinated hydrocarbon insecticides	**	**

*The 50 and 95 percentiles are based on data (1959 to 1970) at Stations 22, 23, 25, and 27 (Figure 1). Data from Stations 26, 28 and 29 are excluded from averaging, because incursions of tidal water (brackish) cause temporarily high values at these stations.

**See narrative

Table 8. Surface water characteristics, Everglades National Park (in mg/l except where otherwise noted)

Station No.	22		23		24		25		26		27		28		29	
Percentile	50%	95%	50%	95%	50%	95%	50%	95%	50%	95%	50%	95%	50%	95%	50%	95%
Physical:																
Color (color units)	40	*	40	*	33	85	17	45	40	90	15	50	10	35	10	40
Turbidity	*	*	*	*	12	22	*	*	8	23	*	*	*	*	*	*
Inorganic Chemicals:																
Bicarbonate	170	192	176	196	164	224	176	272	166	306	160	210	143	200	176	262
Calcium	47	65	50	58	53	75	60	98	50	278	60	78	57	104	60	90
Chloride	37	61	38	58	23	52	17	34	56	252	15	25	60	163	54	124
Fluoride	.3	.3	.3	.3	.2	.4	.2	.3	.3	.5	.2	.4	.2	.2	.2	.3
Dissolved iron	.04	.8	*	*	.03	.2	.01	.06	.05	.3	.01	.03	.01	.04	.01	.07
Magnesium	5.4	8.8	6.4	7.5	5.7	9.8	2.3	3.7	8.8	9.4	3.4	9.2	4.0	7.1	4.0	6.8
Nitrate (as NO_3)	.8	2.3	.9	1.6	.4	1.9	.4	2.4	.8	2.5	.5	5.0	.3	2.8	.3	6.6
Orthophosphate	*	*	*	*	.03	.1	.02	.1	*	*	*	*	*	*	*	*
Potassium	.8	1.2	.7	1.2	.6	2.0	.5	4.8	1.2	77	.4	1.0	.7	1.4	1.0	2.0
Silica	2.8	4.6	1.8	3.1	3.4	10	3.4	40	4.7	7.5	4.1	7.5	2.5	41	3.0	4.7
Sodium	26	39	28	35	15	37	9.4	18	35	464	9.2	19	26	78	30	73
Sulfate	.4	7.6	.4	.8	.8	8.8	.4	2.4	1.2	535	.4	13	.4	4.4	.8	7.2
TDS	198	244	211	247	214	309	178	296	222	1840	191	291	230	434	279	465

*insufficient or no data

RECOMMENDATIONS TO FURTHER DEVELOP AND MAINTAIN WATER QUALITY CRITERIA FOR EVERGLADES NATIONAL PARK

1. A comprehensive sampling and monitoring program of chemical quality in rainfall and dust fallout throughout south and central Florida is needed to supplement existing surface water studies. The sampling program and analyses should be designed to include meteorological data on rainfall and direction of prevailing winds. The investigation should determine quantitatively the extent to which constituents in rain add to constituents already in the water.

2. Because many water quality investigations in central and south Florida are being conducted separately by several Federal, State, and local government agencies, as well as by universities, these should be coordinated and standardized techniques used throughout, i.e., sample collection, preservation, filtering procedures, and analysis, to facilitate comparisons and evaluations of data and findings.

3. Water quality data should be used in computer programs and additional computer programs developed which will enable conversion of data and results from one program to another, as well as presenting data and results tabularly and graphically.

4. Existing water quality programs in south Florida should be expanded to include all reportable constituents, nutrients, insecticides, PCB's, heavy metals, trace elements and physical parameters in water, sediments, and indicator organisms for each trophic level in the food web.

5. Investigate natural biological purification processes involved in spreading backpumped water on the conservation area marshes. Determine loading rates, detention time, biological changes, controls, etc.

6. Investigate injection of water (which would otherwise be backpumped) in the vicinity of the salt-water barrier line in the coastal area for purpose of driving salt water seaward, enlarging fresh groundwater storage. This could reduce the recharge requirements at the conservation areas, and hold a higher quality water in these areas.

7. Investigate effect of evaporation in the conservation areas and canals in increasing concentrations of all suspended and dissolved materials.

8. Investigate low flow and flood routings to park which would provide water of the highest quality.

9. Accelerate biological investigations and sampling to determine acceptable levels for all suspended and dissolved materials.

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APPENDIX

1. Explanation of terms

2. Frequency distribution of selected chemical constituents

3. Excerpt from U.S. Senate report

APPRAISAL OF WATER QUALITY NEEDS AND CRITERIA FOR EVERGLADES NATIONAL PARK

EXPLANATION OF TERMS

An attempt was made to limit the terms used in this report. Wherever possible, preference was given to milligrams per liter (mg/l), rather than to parts per million (ppm). Concentrations of insecticides reported generally are of low order magnitudes, and if consistency in terms is to be maintained, the result is an awkward assembly of ciphers. Also, some insecticides are in tissues or other solids as well as in water. These concentrations would have to be reported as micrograms of pesticide per kilogram of solid, whereas, others would have been in micrograms per liter of water. These objections are overcome by using parts per billion (ppb).

The word "insecticides" is used narrowly in this report, although the text is intended to be sufficiently broad to cover the entire field of pesticides. The narrower term is dictated because laboratory examinations were made only for chlorinated hydrocarbons and not for organophosphates, rodenticides and herbicides. Nonetheless, the presence of these contaminants is no less a concern than the chlorinated hydrocarbons. Future collection and analysis should include all pesticide forms.

FREQUENCY DISTRIBUTION OF SELECTED CHEMICAL CONSTITUENTS

Figures 4, 5 and 6 show the frequency distributions of the concentration of calcium, iron, nitrate, sulfate and total dissolved solids at three locations in and adjacent to Everglades National Park. The data from the stations listed in Table 2 under Tamiami Canal, Shark River Slough, and Taylor Slough were combined to form a composite for each of these three locations. The data were collected between September 1950 and September 1970. The length of each bar represents the number of samples that contained the concentration indicated. For calcium, nitrate and dissolved solids at all locations, and for sulfate at Tamiami Canal, the indicated concentration represents a range, i.e., 30-39 mg/l. All other constituents are represented by discrete values. The final bar at the right of each graph consolidates all the remaining samples whose concentrations were judged atypical, strongly suggesting a sample containing, for example, fresh excreta, an error in the collection or analysis procedure, or a clerical error in data transcription. To lessen the influence of these discrepancies, median rather than mean values are used in this portion of the report.

An analysis of data indicates that seasonal and long term cyclic fluctuations occur, but are not represented in the bar charts, and may cause the multiple peaks observed for some constituents. If a disproportionate number of samples were taken during periods which were peaks or troughs in the cycle, then the bar charts may not be representative of the actual long-term water quality.

Constituent concentrations probably are affected by the rate and/or volume of water flow. For instance, during the dry years of 1962 through 1965 the concentration of nitrate at Tamiami Canal increased significantly. Of the samples taken during this period, 45% had more than 2.0 mg/l nitrate versus 11% for all other years between 1950 and 1970.

Man's alteration of the environment can produce data capable of being at considerable variance with those from a natural condition. These data, when they can be clearly identified, should be excluded from computations used to determine the natural water quality. This was not done, but the data should be further examined to weigh all parameters that may influence the results.

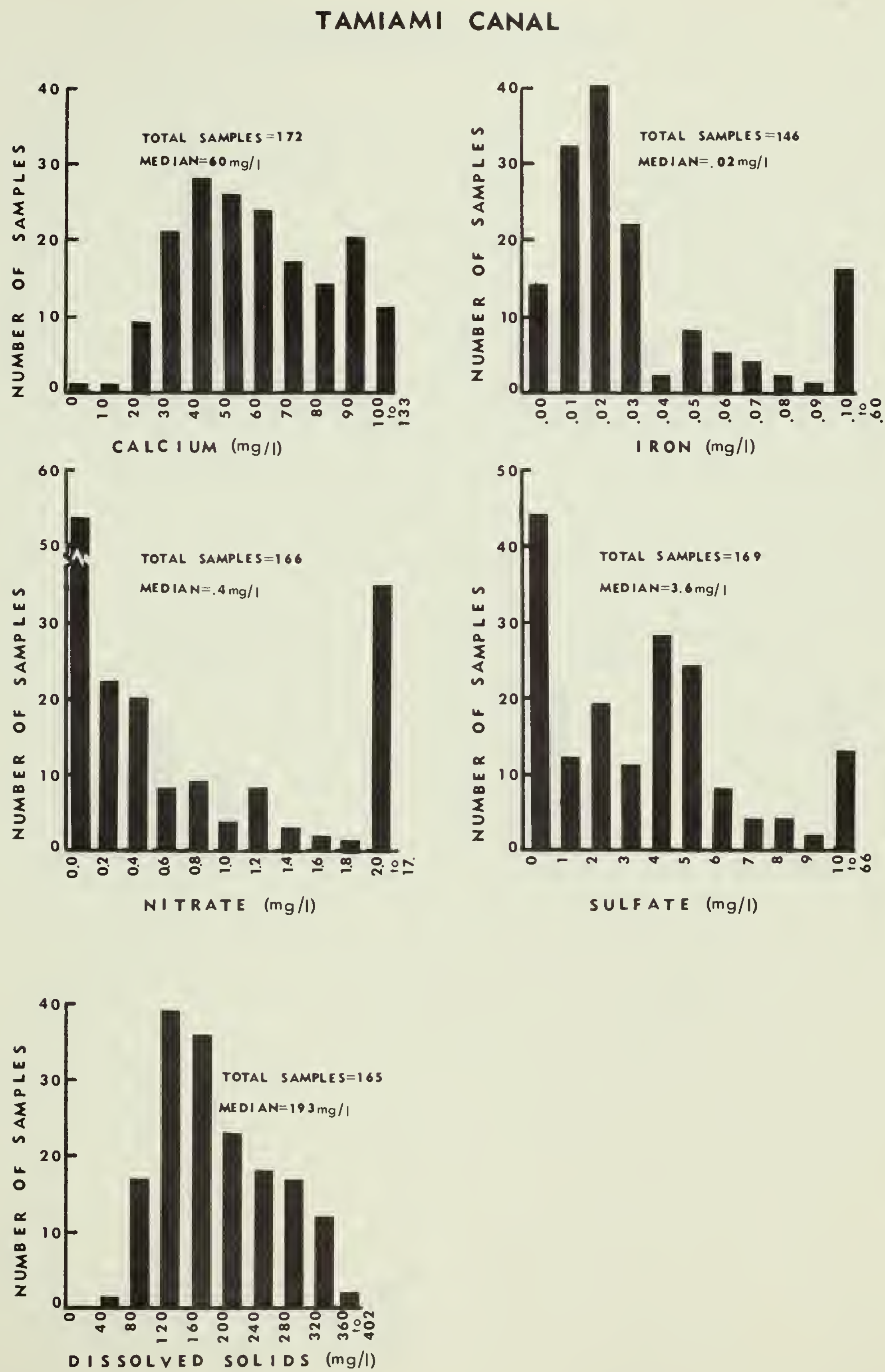

Figure 4. Frequency distribution of selected chemical constituents in waters of Tamiami Canal.

SHARK RIVER SLOUGH

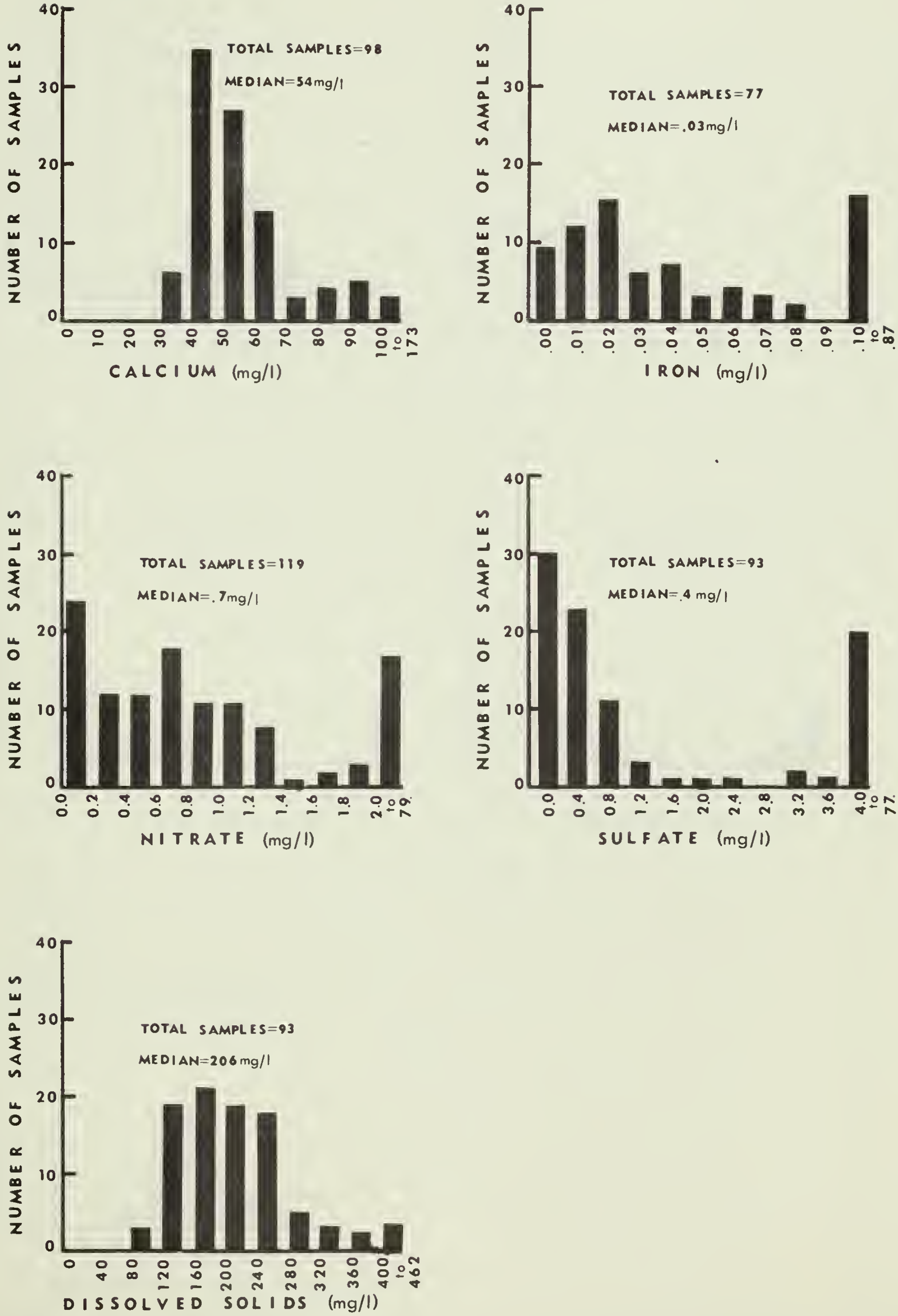

Figure 5. Frequency distribution of selected chemical constituents in waters of Shark River Slough.

TAYLOR SLOUGH

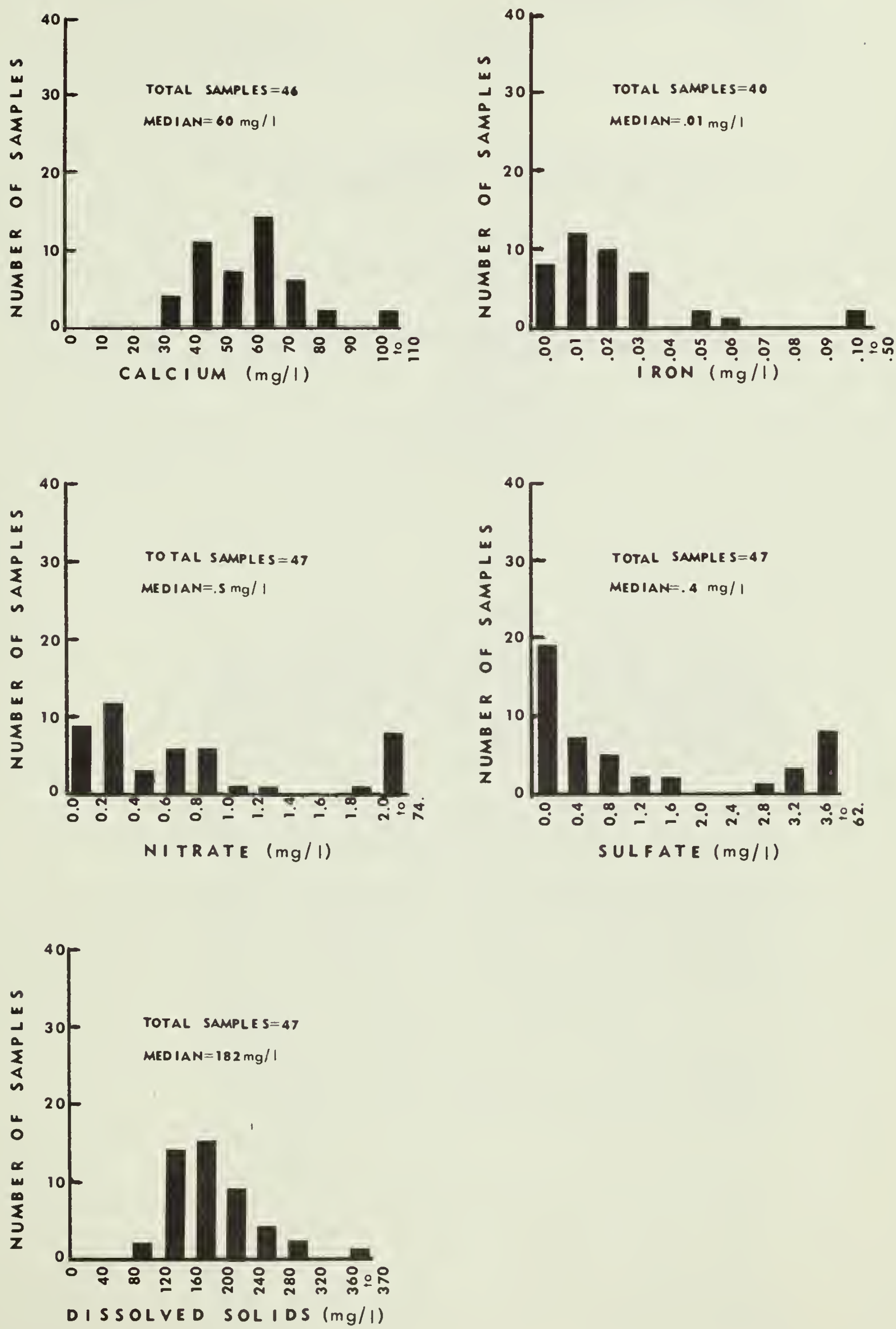

Figure 6. Frequency distribution of selected chemical constituents in waters of Taylor Slough.

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RIVER BASIN MONETARY AUTHORIZATIONS AND MISCELLANEOUS CIVIL WORKS AMENDMENTS

May 26, 1970.—Ordered to be printed

Mr. Randolph, from the Committee on Public Works, submitted the following

REPORT

[To accompany H.R. 15166]

* * *

24

Problems of Water Quality in South Florida

While the language of the legislation is designed to assure an adequate supply of water to the Everglades National Park, in order to preserve the park's unique ecosystem, it is important that consideration be given to the quality of the water delivered. The Corps and the National Park Service should seek to reach an early agreement on measures to assure that the water delivered to the park is of sufficient purity to prevent ecological damage or deterioration of the park's environment.

The major ecosystems of the Everglades National Park are described as: 1. Saw grass prairies, 2. hammocks (hardwood), 3. mangrove salt-water swamps, and 4. salt-water marsh.

It is believed that each of these areas depends on a regular supply of water to perpetuate existing food chains. The key, for example, to the food chains of the prairies and the marshes is algae. The principal threat, in terms of water quality, is that an increase in nutrients would accelerate the growth of algae. This, in turn, would lead to a reduction in the oxygen content of the water and result in a decline in the aquatic population of the park. This, of course, would have an adverse effect on the animal populations that feed upon aquatic animals. Such an acceleration in the accumulation of algae in the water would also lead inevitably to the conversion of these prairies to peat.

At present, the phosphate and nitrogen contents of the Everglades National Park are estimated resepectively at 0.1 parts per million and 1.5 parts per million. These figures compare respectively with 1 part per million and 20–30 parts per million for the effluents discharged from a typical secondary treatment plant. Runoff waters from fertilized fields and suburban gardens can carry substantially greater portions of these nutrients.

The ecology of the Everglades National Park is particularly fragile. A small change in the concentrations of any of the key elements in the water entering the Park could bring a significant change in the park's ecology.

To assure full consideration of the question of water quality, the committee requests that the Corps prepare and submit a report within 1 year on measures that have been taken, and any agreements reached, to assure that the quality of water supplied to the park will not deteriorate, and that the National Park Service prepare and submit a report on the water quality needs of the park and the extent to which they are being met.